JBACHS
Journal of Basic and Clinical Health Sciences

J Basic Clin Health Sci 2024; 8: 55-64
https://doi.org/10.30621/jbachs.1261701
RESEARCH ARTICLE

EFFECT OF ANKLE DISTORTION TAPING ON BALANCE, GAIT, FUNCTION, SPASTICITY AND QUALITY OF LIFE IN CEREBRAL PALSY CASES WITH VARUS DEFORMITY: A RANDOMIZED CONTROLLED TRIAL

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Received: 07.03.2023; **Accepted:** 01.08.2023; **Available Online Date:** 31.01.2024

Cite this article as: Ozden F, Uysal I, Tumturk I, Imerci A. Effect of Ankle Distortion Taping On Balance, Gait, Function, Spasticity and Quality Of Life in Cerebral Palsy Cases with Varus Deformity: A Randomized Controlled Trial. J Basic Clin Health Sci 2024; 8: 55-64.

ABSTRACT

Purpose: The aim of the study was to investigate the effect of ankle distortion taping on balance, gait, function, spasticity and quality of life in cerebral palsy cases with varus deformity.
Material and Methods: A two-armed randomized controlled trial was carried out in rehabilitation center. A total of 32 children with CP were randomized into taping plus conventional therapy (T+CG) and conventional therapy group (CG). The children in the T+CG group were given distortion taping for 3 days in addition to CG. Participants were assessed before the treatment, in the immediate period after the first session, and in the acute period after the third session. The Timed Up and Go Test (TUG) and Single Leg Stance Test (SLST) were used to assess the physical performance-based function. The Modified Ashworth Scale (MAS) was measured the spasticity degree of individuals. Wisconsin Gait Scale (WGS) and Child Health Questionnaire (CHQ) were used to evaluate the gait and quality-of-life, respectively.
Results: The mean ages of the children in CG and T+CG were 9.62±2.50 and 10.0±1.63, respectively. In immediate and acute periods, plantar flexor muscle spasticity decreased significantly in individuals with T+CG ($p=0.0001$). TUG and SLST scores improved significantly in the T+CG group, both in immediate and acute term ($p=0.0001$). In acute and immediate term, there was a statistically significant improvement for WGS in both groups ($p<0.05$). The quality of life of T+CG was improved in the acute period ($p<0.05$).
Conclusion: The results showed the effectiveness of distortion taping in reducing the spasticity of ankle plantar flexor muscles and improving function, balance and gait. However, taping was not superior to control group.

Keywords: ankle varus, cerebral palsy, deformity, distortion method, kinesio taping

INTRODUCTION

Muscle tone problems occur as a result of neurological problems. Cerebral palsy (CP) is one of the most common neurological pathologies causing muscle tone problems. CP is the most specific cause of disability, which induces postural deficits and mobility problems (1, 2). Non-progressive lesions in the brain affect the musculoskeletal system and disrupt muscle architecture in individuals with CP (3). These effects include altered motor function and somatosensory integration, decreased muscle strength, and regular movement pattern (4).

Children with unilateral spastic monoplegic or hemiplegic CP generally have a high degree of physical function [Gross Motor Function Classification System I or II (GMFCS I or II)], and most can walk without assistive devices (5). Previous research has focused more on gait and related therapy for the affected extremity (5, 6). However, in unilateral CP, we can expect gait abnormality with the unaffected side leg due to asymmetry. Investigators encountered a calcaneal deformity with excessive dorsiflexion and valgus in the ankle of children with CP (7, 8).

Surgery, restrained movement, and ergotherapy are commonly utilized during CP therapy. In addition, investigations have highlighted the effect of new methods, including Kinesio Taping (KT) (4). Taping is becoming a more widespread application due to its easy-to-use and inexpensive-to-apply manner. In addition, it can be effortlessly released or replaced to allow other treatment applications. Researchers stated that the purposes of taping in CP are to repair posture disorder, increase the equilibrium of joints, strengthen muscles, reduce spasticity and increase proprioception. However, its clinical evidence is insufficient in children with CP (9).

Kinesio taping helps to increase the sense of proprioception, decrease muscle spasticity and strengthen muscles by affecting the skin, vascular system and motor responses (9, 10). Taping decreases excessive contracture by decreasing spasticity (9). Kinesio Taping also improves joint movement; therefore, it can be used effectively in children with cerebral palsy (11). Decreased spasticity also positively affects functionality, gait, quality of life, and balance in children with cerebral palsy (12).

The deterioration of ankle posture due to varus in the foot causes severe disability in children with CP (13). An ankle distortion taping application aims to improve varus deformity by creating traction towards the neutral position of the ankle with an elastic band. The specific focus of single joint-crossing KT on correction of varus deformity may provide a more effective clinical application compared to other KT methods (14). In this study, we investigated the positive effect of ankle distortion taping on clinical outcomes in individuals with CP. The purpose of the study was to investigate the effect of ankle distortion taping on balance, gait, function, spasticity and quality of life in cerebral palsy cases with varus deformity.

MATERIAL AND METHODS

Study Design

A two-armed randomized controlled trial was carried out in the Fethiye Private Son Atılım Special Education and Rehabilitation Center between March and August 2022. The “CONsolidated Standards of Reporting Trials (CONSORT)” and “Statement of Recommendations for Interventional Trials (SPIRIT)” guidelines were considered during the trial process (15, 16).

Participants

A total of 32 children with monoplegic and hemiplegic spastic CP were included in the study. All patients had an ankle varus deformity. Inclusion criteria of the study were; (1) children with unilateral hemiplegic or monoplegic spastic CP aged 4-12 years, (2) cases at level I or II in the Gross Motor Function Classification System (GMFCS), (3) being able to understand simple commands, and (4) having signed the consent form. Exclusion criteria of the study were; (1) presence of equine deformity, (2) lack of cooperation, (3) history of lower extremity surgery, (4) botulinum toxin administration in the last six months, and (5) allergic reaction on the skin to the taping. Figure 1 summarizes the flowchart of the study.

Sample Size

The sample size calculation was conducted with G-Power 3 software (17) regarding the effect size derived from the similarly designed study's reference values (18). The effect size value was determined as 1.05 according to the changes in the similar parameters of both groups. A total of 24 patients were calculated to be adequate with “80% power and 95% confidence level”. At least 12 cases were found to be sufficient for both groups.

Ethical Consideration

The study was carried out in accordance with the ethical principles and the Helsinki Declaration. Informed consent of the patients was obtained. The study protocol was approved by the clinical research ethics committee of Muğla University (Date: 02.03.2022, Decision No: 5/III). The study protocol was registered (ClinicalTrials.gov Identifier: NCT05251532).

Recruitment Process

Among the children with CP who had varus deformity in the rehabilitation center, those who met the exclusion criteria were informed about the study. The scope of the study, the method, the interventions and the potential benefits and possible side effects of Kinesio Taping were explained. Children and their families who gave their consent were referred to the evaluator therapist.

Randomization and Blinding

A total of 32 children with CP were randomized into taping (conventional therapy applications plus kinesio taping) and control (conventional therapy) groups. “An allocation scheme using the asymptotic maximal procedure” were used in the randomization method (19). “National Institutes of Health National Cancer Institute Clinical Trial Randomization Tool” were used to carry out the randomization (20). No blinding was carried out in the research.

Interventions

All interventions were conducted by a single therapist who is experienced in pediatric rehabilitation and KT for 15 years. Participants were already attending the same conventional rehabilitation before and during the trial. The intervention details of the groups were given below.

Control Group (CG)

Stretching exercises for spastic muscles and cold therapy were applied to manage with spasticity in the CG. In addition, strengthening exercises were applied to the antagonist of spastic muscles. Passive stretches were applied to the peroneus longus and brevis muscles for 40-60 seconds with ten repetitions. Cold packs were also applied to the same muscle group with a dry towel for 10 min. Gait pattern education, strengthening of trunk muscles and joint range of motion exercises were also applied. All

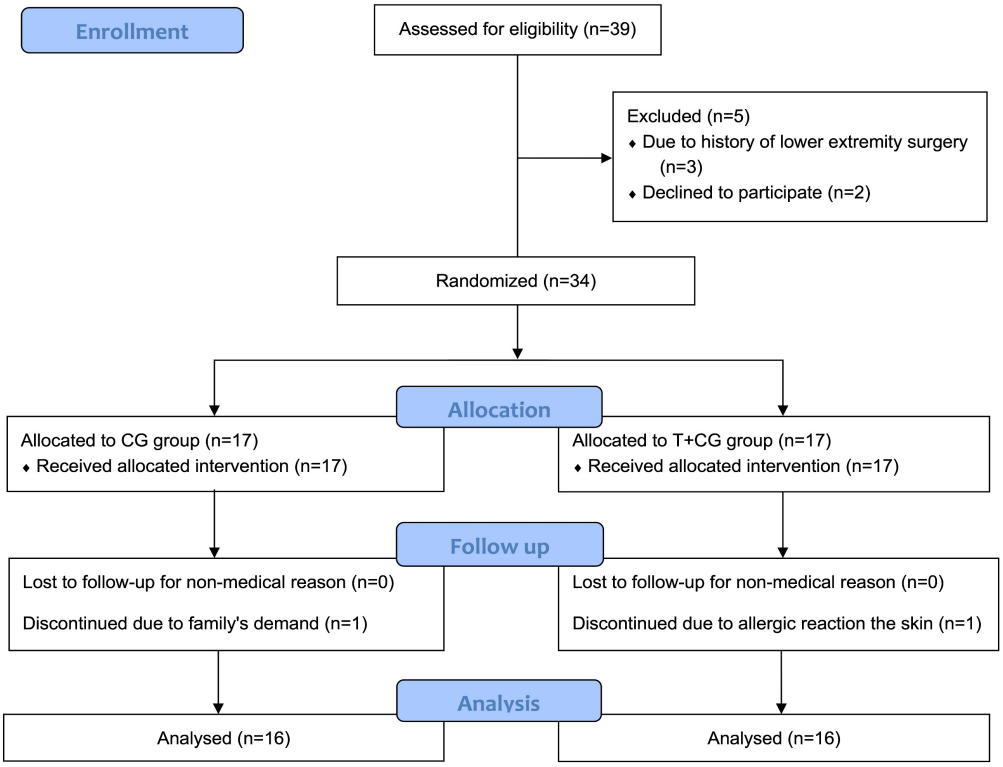

Figure 1. CONSORT Flow chart of the study

applications were performed within a 1-hour rehabilitation session for 3 days.

Taping Plus Conventional Therapy Group (T+CG)

The children in the T+CG group were given additional distortion taping to all the treatments in the CG group. Taping (Kinesio Tex Gold) was applied at the beginning of the first session of the 3-day treatment. Distortion taping protocol was applied to the ankle as previously described. In the first step, while the foot is in the neutral position, the tape is adhered to the anterior capsule with 50% tension. In the second step, the tape is adhered to the malleolus at maximum tension over the calcaneus in neutral foot. If it is desired to prevent abnormal movement directions, corrective pulling is applied in the lateral or medial direction. In the third step, the tape is adhered around the ankle with a half-eight-shaped ligament application. The tape is adhered to the medial malleolus starting from the lateral malleolus around the ankle joint with 70% tension (Figure 2) (14). Taping was removed in the last treatment session on the 3rd day.

Figure 2. Distortion taping application using kinesio taping

Data Collection

Participants were assessed before the treatment, in the immediate period after the first session, and in the acute period after the third session. The Timed Up and Go Test (TUG), Single Leg Stance Test (SLST), Modified Ashworth Scale (MAS), Wisconsin Gait Scale (WGS), and Child Health Questionnaire (CHQ) were used in the evaluations.

Timed Up and Go Test (TUG)

Participants sat in a chair adjusted for their height. They asked to stand up and walk 3 meters forward. Individuals walked the 3-meter pathway again after a 180-degree turn back. Children were then asked to sit on the chair, again. The test time was recorded in seconds. To avoid the effect of fatigue, patients were evaluated at one time and at usual walking speeds (21).

Single Leg Stance Test (SLST)

A secure setting was assembled for the participants near the parallel bar. The child was asked to hold on to the parallel bar and to stand on the unaffected lower extremity. The participant was then asked to remove the hand support from the parallel bar. They asked to maintain balance on one leg. The test time was recorded in seconds. The protocol was completed with a single repetition to avoid the fatigue effect (22).

Modified Ashworth Scale (MAS)

The MAS is a rating scale used to evaluate spasticity in CP. It provides a 6-point rationale to measure muscle resistance with passive movement. The MAS is scored from 0 to 4. A low score represents normal muscle tone, and a high score represents increased muscle tone (23).

Wisconsin Gait Scale (WGS)

WGS provides an assessment with 14 items divided into four subscales based on multi-factor gait analysis. The therapist concludes the results by considering the gait parameters with observational video analysis. The scoring ranges from 13.35 to 42.0. Higher scores indicate higher impairment in gait (24).

Child Health Questionnaire (CHQ)
The CHQ is a standardized multidimensional tool that assesses children with cerebral palsy's functional status and well-being. CHQ's score range is between 0 to 100. Higher scores demonstrate more satisfactory health status in children (25).

Statistical Analysis
Statistical Package for Social Sciences (SPSS) Version 25.0 (SPSS inc, Chicago, IL, USA) was used for the analysis of clinical data. Statistical significance (p) was accepted as 0.05. Continuous variables were presented as mean ± standard deviation. Categorical variables were given as numbers and percentages. One-Sample Kolmogorov-Smirnov Test and Histogram were used to determine the data distribution. Regarding the normality, parametric or non-parametric statistical significance tests were considered the between-group or in-group differences.

RESULTS

Characteristics of the participants
The mean ages of the children in CG and T+CG were 9.62±2.50 and 10.0±1.63, respectively. The individual characteristics of the participants are presented in Table 1. There was no significant difference between the groups (p>0.05). Groups were homogeneous in terms of individual characteristics.

Spasticity
There was no difference in the MAS-based hip flexor, hip adductor, hip internal rotator and knee flexor muscle spasticity between the groups and in-group analysis (p>0.05). In addition, plantar flexor spasticity was not different between the groups. Plantar flexor muscle spasticity decreased significantly in individuals with T+CG (p=0.0001). Detailed post-hoc analysis (Dunn's test) revealed that the significance was due to the pairwise between baseline and 3rd day evaluations (p=0.024) (Table 2).

Function-Balance-Gait
TUG and SLST scores did not differ between groups (p>0.05). TUG and SLST scores improved significantly in the T+CG group (p=0.0001). Post-hoc Dunn test-based difference was significant between baseline and 3rd day (p=0.0001), also 1st day and 3rd day (p=0.014). On the other hand, the post-hoc Dunn test for SLST was significant between baseline and 3rd day (p=0.0001), 1st day and 3rd day (p=0.018). In-group change for CG was not statistically significant (p>0.05). There was a statistically significant difference in both in-group and between-group evaluations of WGS (p<0.05). The difference between baseline and 3rd day (p=0.0001), 1st day and 3rd day (p=0.0001) evaluations for T+CG was significant in the post-hoc test (Table 3).

Table 1. Characteristics of the participants

	CG (n=16)	T+CG (n=16)	p
Age (years, mean±SD)	9.62±2.50	10.0±1.63	0.897[a]
Gender (women/men)	8/8	9/7	0.500[b]
BMI (kg/m^2, mean±SD)	19.37±4.58	17.43±3.22	0.381[a]
GMFCS (level I/II, %)	62.5/37.5	81.3/18.8	0.238[b]
Residency (urban/rural, n)	12/4	15/1	0.166[b]
CP type (hemiplegic/monoplegic, n)	13/3	16/0	0.113[b]
Affected side (right/left, n)	6/10	9/7	0.240[b]
Other chronic disease (yes/no, n)	1/15	1/15	0.758[b]

***SD:** standard deviation, **n:** number of patients, **BMI:** Body Mass Index, **GMFCS:** Gross Motor Function Classification System, **a:** Mann–Whitney U test, **b:** Pearson Chi-Square test*

Quality of Life

There was no difference between the groups regarding the quality of life at baseline (p>0.05). In the intragroup evaluation, an increase was observed in the CG group over time (p=0.002). On the other hand, the quality of life of the participants in T+CG improved over time (p<0.05). Post-hoc Dunn test results were significant for the following pairwise; baseline with 3rd day (p=0.024), and 1st day with 3rd day (p=0.024) (Table 3).

DISCUSSION

The present study focused on the effectiveness of distortion taping on ankle varus in children with CP. The participants' changes in balance, gait, function, spasticity and quality of life were investigated after the taping application. The results showed the efficiency of taping with reduced spasticity of the ankle plantar flexor muscles and improved function, balance and gait. However, taping was not superior to control group.General rehabilitation practice aims to reduce spasticity and increase functionality in the short term with several conventional methods (e.g., stretching, cold) in children with cerebral palsy (26). Therefore, children's balance and gait ability improve during daily life activities (27). On the other hand, these clinical and physical advancements can enhance individuals' quality of life (28). In the present study, we aimed to demonstrate the effectiveness of distortion taping on these parameters (spasticity, function, gait, and balance) by decreasing ankle varus deformity. In other words, our primary hypothesis was to improve conventional applications' advances in the immediate and acute period. Many studies have applied KT to the lower extremity for several purposes (10). However, no study focused on the varus deformity of the ankle by distortion taping application.

A trial in children with hemiplegic cerebral palsy focused on the effectiveness of KT on gait and balance. Özmen et al. applied KT to the gastrocnemius and tibialis anterior muscles. The authors emphasized that KT did not affect plantar flexor muscle spasticity and joint range of motion but showed significant gains in balance and walking during immediate and acute periods. Their results on walking and balance were similar to our study (29).

Table 2. Char In-group and between-group comparison of spasticity

		CG (n=26)	T+CG (n=26)	p (between group)
MAS hip flexor	**Baseline**	0.56±0.60	0.68±0.65	0.590[a]
	1st day	0.56±0.60	0.68±0.65	0.590[a]
	3rd day	0.56±0.60	0.68±0.65	0.590[a]
	p (within group)	1.000[b]	1.000[b]	
MAS hip adductor	**Baseline**	1 (IQR 25/75: 0-1)	0.78±0.68	0.287[a]
	1st day	1 (IQR 25/75: 0-1)	0.78±0.68	0.287[a]
	3rd day	1 (IQR 25/75: 0-1)	0.78±0.68	0.287[a]
	p (within group)	1.000[b]	1.000[b]	
MAS hip internal rotator	**Baseline**	1 (IQR 25/75: 0-1.5)	0.90±0.66	0.128[a]
	1st day	1 (IQR 25/75: 0-1.5)	0.90±0.66	0.128[a]
	3rd day	1 (IQR 25/75: 0-1.5)	0.84±0.62	0.224[a]
	p (within group)	1.000[b]	0.135[b]	
MAS knee flexor	**Baseline**	1.21±0.36	1.31±0.35	0.445[a]
	1st day	1.21±0.36	1.28±0.31	0.491[a]
	3rd day	1.21±0.36	1.25±0.31	0.669[a]
	p (within group)	1.000[b]	0.223[b]	
MAS plantar flexor	**Baseline**	1.34±0.85	1.56±0.25	**0.029[a]**
	1st day	1.34±0.85	1.50±0.31	0.086[a]
	3rd day	1.34±0.85	1.25±0.31	0.867[a]
	p (within group)	1.000[b]	**0.0001[b, c]**	

SD: standard deviation, n: number of patients, MAS: Modified Ashworth Scale, a: Mann–Whitney U test, b: Friedman test, c: post-hoc Dunn test was significant between baseline and 3rd day (p=0.024)

Table 3. In-group and between-group comparison of gait, balance and function

		CG (n=26)	T+CG (n=26)	p (between group)
TUG	**Baseline**	11.03±3.75	12.04±4.63	0.402[a]
	1st day	11.06±3.79	11.58±4.28	0.515[a]
	3rd day	10.96±3.72	11.11±4.33	0.956[a]
	p (within group)	0.939[b]	**0.0001[b, c]**	
SLST	**Baseline**	2 (IQR 25/75: 0-3.96)	1.93±1.60	0.590[a]
	1st day	2.27 (IQR 25/75: 0.25-4.76)	2.24±1.62	0.838[a]
	3rd day	2.34 (IQR 25/75: 1.12-4.57)	2.79±1.70	0.809[a]
	p (within group)	0.562[b]	**0.0001[b, d]**	
WGS	**Baseline**	23.29±7.16	33.44±4.28	**0.0001[a]**
	1st day	23.25±7.14	32.94±4.29	**0.0001[a]**
	3rd day	22.67±6.90	27.60±4.95	**0.011[a]**
	p (within group)	**0.003[b]**	**0.0001[b, e]**	
CHQ	**Baseline**	63.50±17.56	52.70±15.28	0.094[a]
	1st day	63.50±17.56	52.70±15.28	0.094[a]
	3rd day	61.79±17.38	65.95±17.49	0.445[a]
	p (within group)	**0.002[b]**	**0.0001[b, f]**	

SD: standard deviation, n: number of patients, **TUG:** Timed Up and Go Test, **SLST:** Single Leg Stance Test, WGS: Wisconsin Gait Scale, **CHQ:** Child Health Questionnaire, **a:** Mann–Whitney U test, **b:** Friedman test, **c:** post-hoc Dunn test was significant between baseline and 3rd day (p=0.0001), 1st day and 3rd day (p=0.014), **d:** post-hoc Dunn test was significant between baseline and 3rd day (p=0.0001), 1st day and 3rd day (p=0.018), **e:** post-hoc Dunn test was significant between baseline and 3rd day (p=0.0001), 1st day and 3rd day (p=0.0001), **f:** post-hoc Dunn test was significant between baseline and 3rd day (p=0.0001), 1st day and 3rd day (p=0.0001)

Oppositely to Özmen et al., KT also reduced plantar flexor muscle spasticity in our study after three days of treatment (acute effect). The results might have been different due to the differences in the KT methods regarding the obvious sample characteristics similarity of the two studies. Future studies may focus on the advantage of distortion taping in reducing spasticity using computerized analysis to provide more factual data.

In another study, 12-week results of KT to both the upper and lower extremities in children with unilateral spastic CP were investigated. The researchers applied KT with an "I" shape technique with facilitation and correction methods. They reported that KT constructed significant contributions to proprioception, physical fitness, gross motor function and activities of daily living (30). Compared to our study, functional gains were monitored, and positive effects of KT were demonstrated for 12 weeks.

A recent placebo-controlled study showed that KT increases rectus femoris muscle activity and ankle joint range of motion in children with unilateral CP. Although this application was performed on the knee with a different technique and application area, the results should still have an essence in increasing muscle activity and ROM in the immediate period (31). The functional gains achieved in our study may have been achieved through muscular activation, especially in the foot-ankle muscles and tendons in this context. On the other hand, in another recent study, the application of Y tape to the gluteus maximus muscle in children with CP improved gait parameters in the acute period, suggesting that KT may provide significant advantages in increasing muscular activation in the general context (32).

A recent randomized controlled study reported a positive effect of KT combined with lower extremity orthoses on gait parameters in children with spastic CP during four weeks of follow-up. The authors supported the spatiotemporal parameters with the GAITRite System with objective data (33). Our study also provided the positive gains of KT in the immediate and acute period on the walking parameters by WGS. Considering that WGS is a subjective tool, the objective-subjective outcome agreement revealed the positive effect of KT on walking more solidly. In particular, the 4-week long-term gain relative to the shorter-term follow-up in our

study enabled us to interpret that the distortion-taping technique can also provide promising long-term results.

The pilot study in 2019 focused on the immediate effectiveness of KT, similar to our study. The authors emphasized that the neuromuscular taping technique affects static balance positively, but there was an insufficient advancement in dynamic balance (34). These results obtained in children with hemiplegic CP at GMFCS level I emphasized significant gains in TUG, likewise our TUG and SLST score improvements. Actually, TUG also includes dynamic balance tasks (e.g., gait and turns) (21). A sensor-based measurement can reveal the improvements in static and dynamic balance more clearly. However, available data have revealed that KT can provide positive effects in both static and some dynamic activities requiring balance in the acute period.

One aspect that assembles our study unique is the quality-of-life assessment. KT may not affect an individual's quality of life in the short term. However, we envisioned that KT intervention during the 3-day can positively affect the individual's vital activities related to some quality-of-life parameters. Our results showed that KT could contribute more (although not statistically significant) to the quality of life compared to conventional applications. Future studies should incorporate a more comprehensive assessment of the impact of KT on the quality of life in children with CP.

Limitations

First, our study merely investigated KT's immediate and acute period efficacy. A long-term follow-up may focus on the follow-up of 3-6 months of KT administration, repeated at 3-day intervals. Second, blinding was not possible due to the current practical conditions and the nature of the study. Future studies could address assessor and therapist blindness to avoid methodological bias. Finally, sensor-based and computerized devices could provide more sensitive data for spasticity and balance measurement.

CONCLUSION

The results showed the effectiveness of distortion taping in reducing the spasticity of ankle plantar flexor muscles and improving function, balance and gait. However, taping was not superior to control group. In clinical practice, KT may be a simple and low-cost complementary method for children with ankle varus deformities.

Acknowledgement: None.

Author contribution: Conceptualization: Fatih Özden, İsmail Uysal; Methodology: Fatih Özden, İsmail Uysal; Formal analysis and investigation: İsmet Tümtürk, Ahmet İmerci; Writing - original draft preparation: Fatih Özden, İsmail Uysal, İsmet Tümtürk, Ahmet İmerci; Writing - review and editing: Fatih Özden, İsmail Uysal, İsmet Tümtürk, Ahmet İmerci

Conflict of interests: The authors report no conflicts of interest and certify that no funding has been received for this study and/or preparation of this manuscriptThe authors declare no conflict of interest.

Ethical approval: The study was carried out in accordance with the ethical principles and the Helsinki Declaration. Informed consent of the patients was obtained. The study protocol was approved by the clinical research ethics committee of Muğla University (Date: 02.03.2022, Decision No: 5/III). The study protocol was registered (ClinicalTrials.gov Identifier: NCT05251532).

Funding: None

Peer-review: Externally peer-reviewed.

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